



# An evaluation of Scottish woodland grant schemes using site suitability modelling



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## ABSTRACT

Woodland expansion is a key component of Scottish land use policy, with targets to increase woodland cover from 18% towards 25% of land area by 2050. However, to date there has been little assessment of whether forestry policy is achieving its objectives. Here, we present an evaluation of woodland grant schemes based on site suitability modelling for the Lochaber Forest District in northwest Scotland. We perform a spatial analysis of woodland creation between 1988 and 2014 using site suitability scores generated through the Forest Research Ecological Site Classification (ESC) methodology. We further conduct in-depth interviews with fourteen stakeholders within the grant-scheme application process to explore the influence of ecological suitability on woodland planning. We find that 92% of woodlands are suited to current climate conditions, and that suitability has improved under the latest grant scheme. This is concurrent with an increased emphasis on suitability modelling in decision-making, though could be explained by cultural changes or a more rigorous approvals process. We find that ecological variables are used to inform woodland location and species selection, but that woodland type is more commonly determined by grant structure. Finally, we discuss other potential limits to grant scheme success, including climate change, edaphic variables and woodland management.

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## 1. Introduction

The Scottish Government has set out policy to increase woodland from 18% of land cover towards 25% by 2050, requiring the creation of approximately 10,000 ha of woodland per year (Scottish Executive, 2006; WEAG, 2012). Much of this expansion will take place on private land but be publicly subsidised through woodland grant schemes (Sing et al., 2013). Subsidies are justified by the social and environmental benefits of woodland, including habitat restoration, carbon storage and recreation (FCS, 2009). However, these benefits vary by woodland type and over woodland lifetime, and are not necessarily guaranteed (van der Horst and Gimona, 2005). Despite this, there has been very little evaluation of woodland grant schemes, primarily due to the long time scales associated with woodland growth (Thomas et al., 2015). To account for the time-lag between planting and longer-term woodland benefits, we assess whether modelled site conditions, particularly climate, will constrain growth or establishment for woodland planted over the last 25 years in the Lochaber Forest District, Scotland.

### 1.1. Background and context

#### 1.1.1. Woodland grant schemes in Scotland

Approximately one third of woodland in Scotland is managed on behalf of the public by the UK Forestry Commission (FC, 2015). In these woodlands, decisions are guided by benefits arising to the public as a whole. However, two thirds of Scottish woodland is privately owned and the majority of future expansion is expected to take place on private land (Sing et al., 2013). In this case, decisions are largely shaped by private benefits accruing to landowners, even though additional public benefits arise as a result (Urquhart et al., 2010). Grant schemes address this market failure by offering incentives to create woodlands that generate social and environmental benefits (FCS, 2010). Grants contribute to planting costs, with additional payments available for woodland expansion on agricultural land. There have been six woodland grant schemes in Scotland since grants replaced tax incentives in 1988 (Table 1). At present, grants are provided through the Scottish Rural Development Programme (SRDP), now in its second stage. (Table 2).

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<sup>1</sup> Soil classification based on the 1:250,000 Soil Survey of Scotland National Soil Inventory (The Macauley Institute for Soil Research, 1984).

**Table 1**  
Woodland Grant Schemes in Scotland.

Woodland Grant Scheme	Period
Woodland Grant Scheme 1 (WGS1)	1988–1991
Woodland Grant Scheme 2 (WGS2)	1991–1994
Woodland Grant Scheme 3 (WGS3)	1994–2003
Scottish Forestry Grant Scheme (SFGS)	2003–2006
Scottish Rural Development Plan (SRDP) 1	2007–2014
Scottish Rural Development Plan (SRDP) 2	2014–2020

An estimated 89.5% of private woodland creation in Scotland from 1992 to 2001 would not have occurred without grant aid, though this varies by scheme (CJC Consulting, 2002). Grant structures have also been instrumental in determining new woodland type (Lawrence and Edwards, 2013). However, planting rates remain well below those of the 1980s, and are falling short of targets (Scottish Government, 2010; Wilson, 2011). Multi-functional, native woodland is also now favoured over commercial conifer plantation, such that softwood production is predicted to fall sharply after 2030 (Slee, 2005; WEAG, 2012; FC, 2014a).

### 1.1.2. Woodland suitability

The limited evaluation of woodland grant schemes to date appears to be particular to forestry, since similar agricultural schemes have received significant attention (Kleijn and Sutherland, 2003; Lahmar, 2010; Pe'er et al., 2014). One major difference is the associated timescales, since it can take decades to centuries for woodland to reach maturity (Clegg and Co., 2002). However, it may also reflect the infancy of methodologies and low priority for evaluation (Aronson et al., 2010). One approach that takes these limitations into account is the evaluation of site suitability, since woodlands that are unsuited to local climate (Ennos et al., 1998) or soils (Wilson et al., 2005) exhibit low growth rates or fail to establish entirely (Lee et al., 2002). In woodlands planted in Scotland between 1992 and 2001, CJC Consulting (2002) found that climatic factors accounted for approximately one fifth of heavy losses. Similarly, inappropriate species selection for local climate has been recognised anecdotally as contributing to the failure of several woodland expansion projects, though evidence for this is limited (Ennos et al., 1998; Gordon Patterson pers. comm. 16/07/14). While damage from extreme weather events is unavoidable, the extent to which temperature, precipitation and exposure variables are formally considered in selection of woodland species or seed provenance is unclear.

### 1.1.3. Ecological suitability

Ecological suitability here refers to the climatic and edaphic suitability of sites for tree species. Formal assessment of ecological conditions as part of the woodland planning processes is strongly encouraged in Scotland. Many priority areas for forestry, notably the Scottish Highlands (Towers et al., 2006), experience cold annual temperatures, high precipitation, and strong winds (Mayes and Wheeler, 2013). Furthermore, basing species selection on existing woodland communities is often impossible due to a legacy of intensive land use that has heavily modified vegetation communities (Barnes and Pregitzer, 1982; Ennos et al., 1998; Quine et al., 2002). Site assessment is aided by land designation and local Forest and Woodland Strategies, which indicate priority areas for forestry based on site suitability, existing land use and community impacts, among other factors (FCS, 2010). However, evidence from Wales suggests that designations are often overruled (Wynne-Jones, 2013). Decision support tools such as the Forestry Commission's 'Ecological Site Classification' (ESC) are also actively promoted in woodland planning and are used by approximately one third of private foresters in the UK (Stewart et al., 2013). In the Scottish Highlands, ESC outputs or similar evidence

are now required under the SRDP to justify woodland creation in marginal sites (FCS, 2012). However, the impact of this is unknown. Understanding whether ecological conditions will limit woodland benefits, and how this is accounted for in land use planning, would therefore greatly aid the effective design of future policy and grant scheme structures.

## 1.2. Study aims

We use existing methods of spatial analysis and qualitative research to examine the extent to which ecological suitability may constrain woodland creation in the Lochaber Forest District, Scotland. We perform a post-hoc assessment of site suitability using ESC methodology to investigate whether grant-funded woodland expansion since 1989 has been appropriate for site conditions. We further investigate the role of ecological suitability and modelling tools in the woodland creation planning process through interviews with key stakeholders.

## 2. Methods

### 2.1. Study area

The study was carried out in the Lochaber Forest District in the Western Highlands of Scotland (Fig. 1; Table 2). Lochaber has a mountainous landscape, with land use dominated by sport-hunting estates and forestry (FCS, 2014). In 2011 the total forest area in Lochaber was 83,877 ha, accounting for 17% of land area (FC, 2012). The dominant woodland type is conifer (56%), mainly *Picea sitchensis*. Successive woodland inventories indicate that woodland area has increased by 6,253 ha (8%) since 1998 (FC, 2015). Grant scheme approvals account for 6% of woodland expansion under the SRDP. Woodland planning is primarily carried out by a small number of forestry agents and monitored by Forestry Commission Scotland, The Highland Council and Scottish Natural Heritage (SNH).

### 2.2. Spatial evaluation of climatic suitability

#### 2.2.1. Data collection

We collated records of woodland creation in Lochaber from publicly available datasets covering grant schemes between 1989 and 2014 (FC, 2014b; Supplementary materials). Scottish Forestry Grant Scheme (SFGS) data were excluded because we could not distinguish woodland creation from other forestry activities. Forestry Commission Scotland provided additional species composition mapping under the SRDP. This information was unavailable for previous grant schemes beyond distinction between broadleaf (including *Pinus sylvestris* as an 'honorary broadleaf') and conifer woodland.

#### 2.2.2. Climate suitability modelling

We assessed the climatic suitability of site location and species selection using suitability maps generated using ESC methodology at a resolution of 250 m<sup>2</sup> (Bathgate, 2011). ESC matches four climatic and two edaphic variables with the ecological requirements of tree species using a knowledge-based model (Table 3; Pojar et al., 1987; Pyatt et al., 2001). A detailed description of ESC methodology is outlined by Pyatt and Suarez (1997) and Pyatt et al. (2001). Since it was not possible to collect soil samples from study sites, soil variables were not included in spatial evaluation. A separate analysis was conducted for edaphic suitability.

We selected the most abundant tree species in the district to model suitability scores (Supplementary materials). To account for unknown species composition, we generated broadleaf and conifer species-assemblage maps based on the weighted

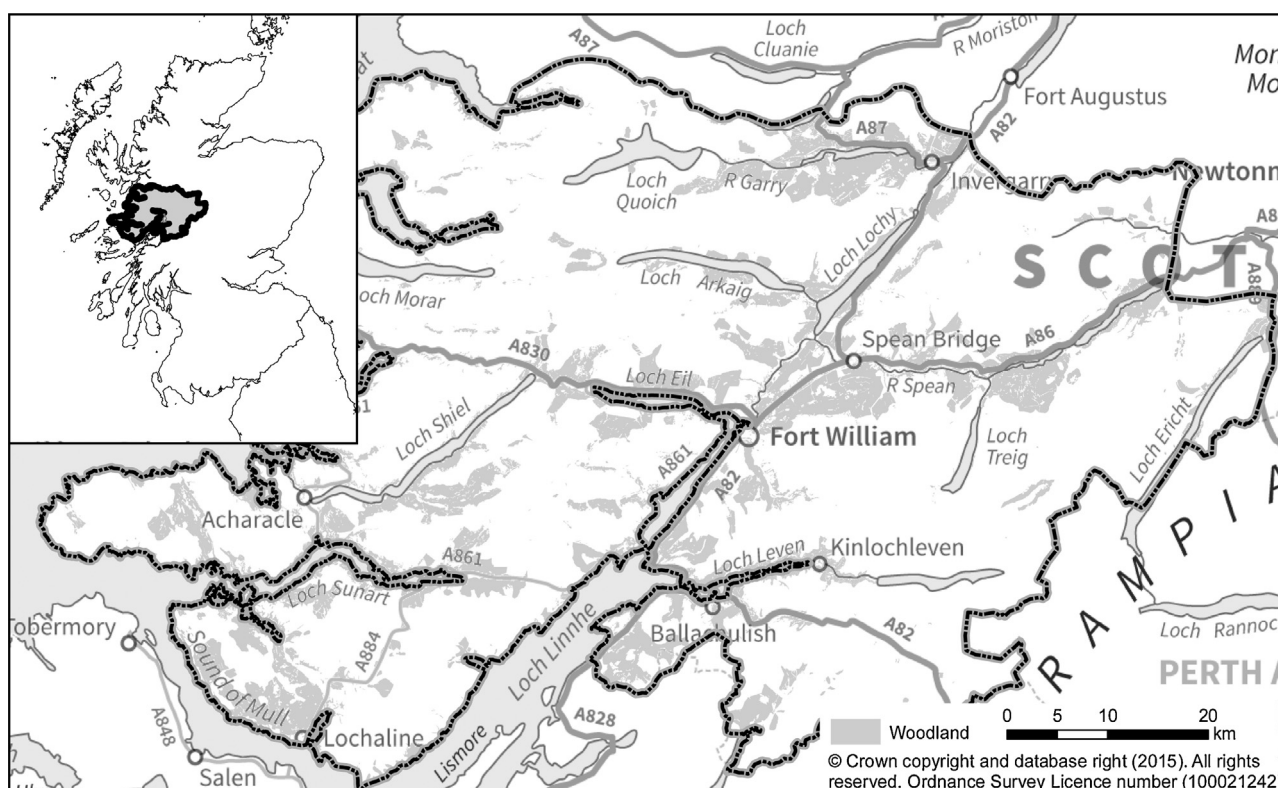


Fig. 1. Map of Lochaber Forest District indicating position within Scotland and woodland area.

**Table 2**  
Ecological variables in Lochaber (FCS, 2014).

Climate	Atlantic maritime climate: cool, wet winters and warm, wet summers. Rainfall approximately 2000 mm/yr.
Water	District dominated by the Great Glen, including major catchments of Glen Garry, Glen Spean and Glen Nevis. Year-round snow on Ben Nevis stabilises water balance.
Soils	Predominantly upland peats <sup>1</sup> with iron-pans and low-nutrient deep peats in the uplands due to heavy rainfall. Peaty-gleys and forest brown-earths on lower slopes.
Habitats	Nationally important Atlantic oakwoods, upland birch woodlands and remnant pine forest, in addition to open-moorland and mountaintop environments.

**Table 3**  
Variables used in ESC methodology (Pyatt et al., 2001).

Variable	Description	Included in model
Accumulated Temperature	Number of degree days per year >5 °C, representing warmth required for growth.	Yes
Moisture Deficit	Difference between summer evaporation and rainfall, representing water availability.	Yes
Windiness	Based on 'Detailed Aspect Method of Scoring' (Quine and White, 1994), representing wind strength and frequency.	Yes
Continentality	Based on the Conrad Index (Birse, 1971), representing seasonal climate variation.	Yes
Soil Moisture	Based on soil type, representing moisture availability.	No
Soil Nutrients	Estimated from soil characteristics and vegetation layer, representing nutrient availability.	No

composition of native woodland under the SRDP (broadleaf woodland), and *P. sitchensis* for conifer woodland. We generated output suitability raster maps for each species and species-assemblage. Every pixel was assigned a suitability score between 0 and 1 (<0.30–Unsuitable; 0.30–0.50–Marginal; 0.50–0.75–Suitable; >0.75–Very Suitable, based on Pyatt et al., 2001).

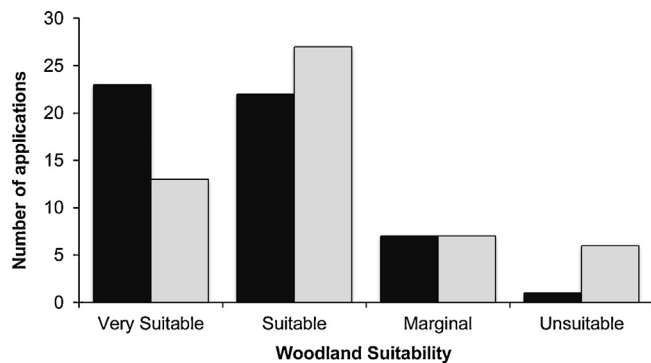
### 2.2.3. Site suitability assessment

Woodland creation polygons were overlaid on output suitability maps to generate suitability scores for each woodland. Pixels were counted if >50% lay inside the woodland polygon. Scores were weighted by species composition to provide an overall suitability score for each polygon. We conducted two analyses, (i) SRDP only, using detailed species composition, and (ii) all grant schemes, using species assemblages. Differences between approaches and

woodland grant schemes were tested using ANOVA and t-tests. We examined within-woodland variability by examining the proportion of woodland area with a suitability score <0.3. Woodland location was tested for randomness by comparing 10,000 randomly sampled pixels with 10,000 random woodland pixels using two-tailed t-tests. Spatial analysis was conducted in QGIS 2.4 (QGIS, 2014). Statistical calculations were performed using Microsoft Excel Version 14.4.8 (Microsoft, 2011) and R Version 3.2.0 (R Development Core Team, 2015).

### 2.3. Evaluation of edaphic suitability

Edaphic suitability was investigated at the landscape scale by generating suitability scores for soil moisture and soil nutrients using the online ESC tool (Forest Research, 2015). Soil inputs were



**Fig. 2.** Suitability of woodland planted under the Scottish Rural Development Plan. Black bars represent mean woodland scores. Grey bars represent scores within one standard deviation of the mean.

based on the National Soil Inventory at a resolution of 5 km<sup>2</sup> (Lilly et al., 2010). Site location was based on the grid reference or central coordinates of woodland sites.

#### 2.4. Role of ecological suitability in woodland planning

We investigated the role of ecological suitability and modelling in decision-making through semi-structured interviews with key stakeholders. Interviews also provided a means to explore spatial findings in more depth (Berg, 2004). We limited scope to forestry agents, and stakeholders from the three mandatory decision making bodies (Table 4) since we considered these to exert greatest influence over planning. Together, interview respondents had worked on all SRDP applications in the region. We identified forestry agents from grant applications and discussions with Forestry Commission Scotland. All but two forestry agencies operating in the area took part in interviews. Landowners were not included in interviews. We also interviewed representatives from Forest Research on the development and use of ESC. Fourteen interviews were conducted in total, representing five stakeholder groups. Interviews were carried out face-to-face or by phone and were transcribed in full.

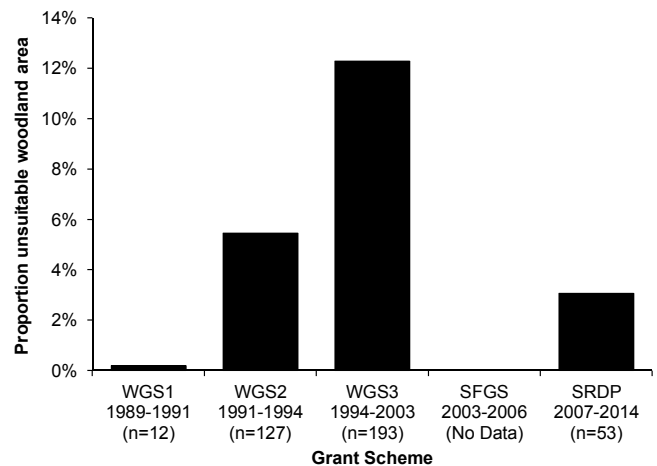
### 3. Results

#### 3.1. Climatic suitability of new woodland

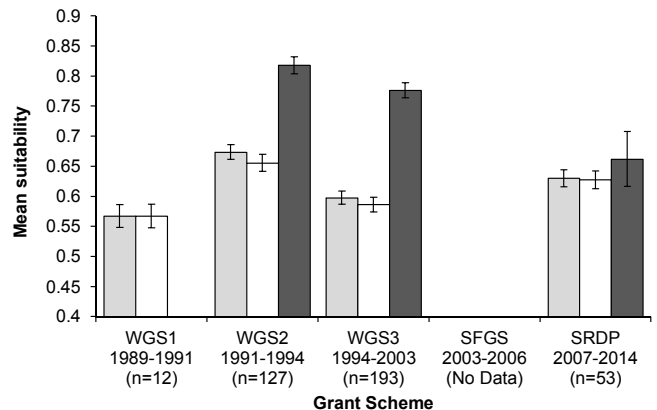
##### 3.1.1. Scottish rural development plan (2007–2014)

A total of 53 woodland creation applications had been approved in Lochaber under the SRDP at the time of research (August 2014). 47 applications were for native woodland, 4 for productive conifer, and 2 for mixed woodland. The majority of applications relied on direct planting, with only six woodlands using natural regeneration.

Based on species composition maps, 83% of new woodlands were climatically suitable or very suitable. Only one application was unsuited to local climate, accounting for 3% of new woodland area, though six applications (12% of area) were unsuitable within one standard deviation (Fig. 2). *Alnus glutinosa* and wet woodland species were least suited to sites with mean suitability scores of 0.37 and 0.48 respectively, in line with previous findings by Ogilvy (2004). However, these may be located in microclimates that are inadequately modelled by ESC. *P. sitchensis* (0.78) and *Betula* spp. (0.71) woodlands were most suited to sites. Woodland locations differed significantly ( $p < 0.01$ ) from random spatial sampling.



**Fig. 3.** Proportion of climatically unsuitable woodland planted under Scottish Woodland Grant Schemes (1989–2014). Woodland is considered climatically unsuitable if it has a suitability score of  $< 0.3$ . Data not available for the SFGS.



**Fig. 4.** Mean climatic suitability of Scottish Woodland Grant Schemes. Light grey bars represent mean suitability for all woodlands, white bars broadleaf woodland, and dark grey bars coniferous woodland. Error bars indicate one standard error. Data not available for the SFGS.

##### 3.1.2. All woodland grant schemes (1989–2014)

Based on estimated species assemblages, 76.5% of woodlands were climatically suitable or very suitable. Of 385 grant applications, only five were unsuited to climatic conditions (0.7% of woodland area). However, taking account of within-woodland variability, 8% of woodland area (0–12% by scheme) was unsuited to climatic conditions (Fig. 3). There was a statistically significant increase in suitable area from 88% under WGS3 to 97% under the SRDP ( $p < 0.05$ ).

There was no significant change in the mean climatic suitability of woodlands across all applications (Fig. 4). In general conifer woodland was located in more climatically suitable areas than native woodland, though this difference decreased over time ( $p < 0.01$ ). Climatic suitability of native woodland decreased between 1991 and 2003 ( $p < 0.05$ ), but there was no significant change under the SRDP. There was close correspondence between suitability for the SRDP under both modelling approaches.

#### 3.2. Edaphic suitability of new woodland

48% of applications (44% of woodland area) were edaphically suitable or very suitable. 51% of applications (56% of area) were marginal, while only two applications (1%,  $< 0.01$  of area) were unsuitable. However, due to the coarse resolution of underlying



**Table 4**  
Stakeholder groups represented in interviews.

Stakeholder Group	Description	No. of Interviews
Forestry Agents	Professional forester employed by landowner to manage woodland creation.	6
Forestry Commission	Responsible for National Forest Estate and approval of woodland expansion applications.	4
Forest Research	Conduct a range of forestry research, including the development of ESC.	2
Highland Council	Statutory consultee for woodland creation, representing local communities.	1
Scottish Natural Heritage	Statutory consultee for woodland creation, representing conservation, habitat and landscape interests.	1

soil data only a small number of unique suitability values were obtained. This prevented the generation of meaningful output distributions (Supplementary materials). As such, we have low confidence that ESC outputs adequately reflect site characteristics.

### 3.3. Influence of climate suitability on woodland planning

#### 3.3.1. The decision-making process for woodland expansion

A four-stage conceptual model of the woodland expansion decision-making process is outlined in Fig. 5. While interviews focused on ecological suitability, it was clear that decision-making is also contingent on economic, landscape, and community considerations, among other factors. This model applies specifically to the woodland planning process, and does not include motivations for woodland vis-à-vis other land uses (see Lawrence and Dandy, 2014), or activities taking place once approval has been granted.

**Stage 1: suitability for woodland.** The first stage of the decision-making process is an initial, high-level site analysis. Woodland is often of low priority to landowners and as such woodland may only be considered if no other land use is possible.

*“People think ‘we’ve got a spare patch of land’ and it’s usually a peat bog. It can’t be used because it’s a bog but that also means it’s not suitable for trees. . . nobody is interested in that land, not even a forester.”*

Forestry agent

Initial evaluation may take the form of a brief site visit or desk-top analysis, but rarely involves detailed assessment. Suitability is primarily determined by edaphic considerations, most notably the presence of peat, but also incorporates factors such as land designation and access.

**Stage 2: high-welfare woodland type.** Should the site be considered suitable for woodland, design is usually based on selection of either native or productive woodland. Although some agents argued that this dichotomy need not occur, for example by planting *P. sylvestris* as a commercial crop, decisions are nonetheless dependent upon objectives rather than ecologically suitable species.

*“In terms of objectives it’s normally native or commercial. We might be able to influence which one they think about but the objectives are usually financial. They’ll want to know how they can make money from woodland.”*

Forestry agent

Forestry agents repeatedly emphasised the importance of grant rates in determining woodland type. Commercial woodland would require investment by the owner, in contrast to the immediate return of native woodland grants. As such, native woodlands made up the majority of new planting. In some cases, agents stated that owners had revised plans for commercial woodland upon receiving financial estimates, instead planting native species. Market considerations such as international demand and timber production forecasts were rarely mentioned. Some owners were also described as having a strong conservation ethic or the desire to leave a positive legacy for future generations, though this was rare.

**Stage 3: species selection.** Once woodland type has been identified, species are selected from the subset of available native or productive species, according to site suitability. This is primarily

dependent upon soil characteristics, local climate, and existing vegetation. Information is gathered through site surveys, with varying use of ecological modelling tools such as ESC.

Vegetation surveys were considered the best indicator for species selection where existing woodland was present. However, many stakeholders stated that heavy modification of upland environments meant that remaining vegetation communities were rarely informative of potential woodland. Consequently, both agents and the Forestry Commission viewed soil variables as the most useful indicator of site suitability. However, high variability in soil type within Lochaber was emphasised as a barrier to effective species selection. In contrast, climatic factors were considered of low importance except in microsites. Finally, the cost and availability of seed sources was stated to influence selection, with cheaper species such as *Betula* spp. favoured.

**Stage 4: consultation and approval.** All new woodland applications are subject to approval by the Forestry Commission, in addition to a 28-day public consultation period. Further approval is required from SNH and the Highland Council as statutory consultees. Woodland applications must demonstrate appropriate site and species selection. This necessarily goes beyond ecological variables and takes into account landscape, existing habitats, and community concerns such as access and water supply. Applications must be supported by evidence, including soil data, ESC outputs and landscape assessment.

While it is rare for applications to be rejected, this stage can cause significant delays. The approval process typically takes three to six months in the case of “good, well founded, appropriate applications”, but potentially up to several years if modifications are required. This is partly due to resource limitations and partly due to insufficient supporting evidence. Delays were a cause of frustration to consultees, forestry agents and owners. It was felt that the application process was becoming more complex, linked to increasing grant value and regulation from various bodies. This was reflected by stakeholders on both sides of the approval process, though was seen not as an issue of purpose, but of process.

*“I don’t think there’s a problem with what they’re trying to do in the SRDP. It’s just the way they have gone about it, it’s very complicated and time consuming to do.”*

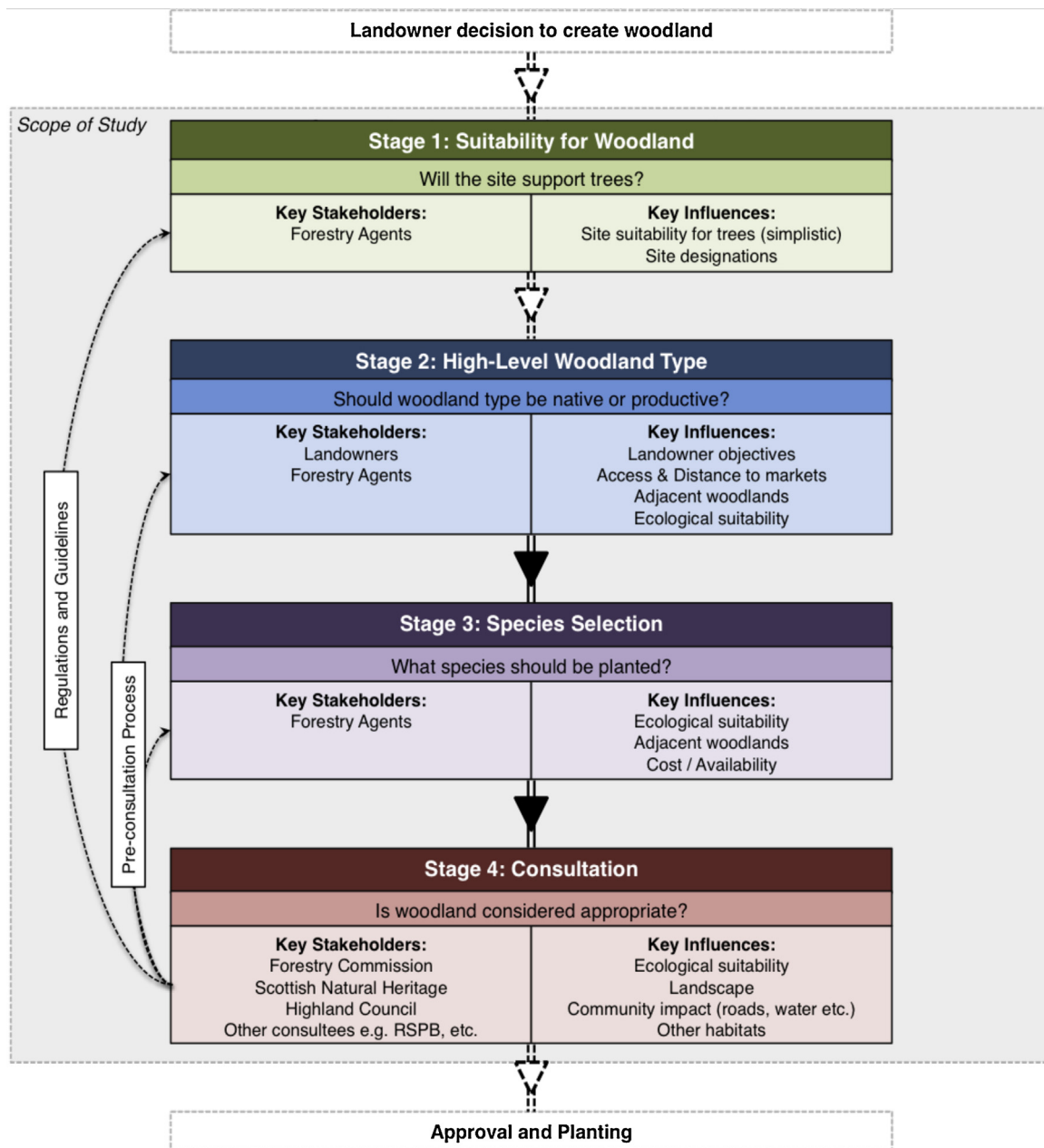
Forestry agent

There was some evidence that pre-consultation and the use of the Highland Forests and Woodlands Strategy (Highland Council, 2006) were improving the process by highlighting potential issues early on. However, some forestry agents saw this as excessive interference on behalf of external bodies.

#### 3.3.2. Use of ecological site classification in the planning process

All forestry agents had some experience of ESC, though fewer than half used it regularly. ESC analysis was mainly implemented in the species selection (Stage 3) and approval (Stage 4) stages of the decision-making process, and had four major uses.

**Informing species choice.** Analysis of ecological parameters enabled the identification of appropriate species for a given site. While the intended purpose of ESC, few agents stated that they used it in this way.



**Fig. 5.** Conceptual model of the woodland planning process. Planning goes through four stages (i) consideration of site suitability, (ii) consideration of woodland type, (iii) species selection, and (iv) public consultation. Key stakeholders and influences on each stage are outlined, in addition to links between stages arising from regulations and pre-consultation.

**Supporting decision-making.** More commonly, agents stated that ESC was used to confirm decisions already made.

*"I have used some of the information to almost back up some of my decisions rather than the other way round, rather than using it to dictate."*

Forestry agent

While generally considered reliable, ESC outputs were commonly dismissed if they did not support the agents' decisions. Agents referred to limitations of ESC, or argued that site indicators such as existing vegetation contradicted outputs. This relied heavily on the experience of foresters who "have been around a lot longer than ESC has". No instances where ESC outputs had altered woodland design were encountered.

**Justifying applications.** Forestry agents used ESC to justify woodland applications to the Forestry Commission. This was par-

ticularly the case for larger projects, which facilitated higher budgetary and time requirements for analysis. However, there was some suggestion of selective use, whereby evidence was only supplied when outputs supported the application. Some also suggested that "you can bend or twist [ESC] to give out what you want", enabling outputs to be shaped by decisions, rather than vice-versa.

**Assessing applications.** The use of ESC by the Forestry Commission to evaluate applications appeared to be influential, but not critical. There was a view that agents could be trusted, and that experience was valued above modelling. However, where sites were marginal, ESC outputs would be required to support applications, and would inform disputes over the selection of species or seed sources.

Overall, ESC was viewed as a useful but not essential "tool in the toolbox", though one with a number of limitations. These included high sensitivity to inputs, particularly soil nutrients, and the cost

of gathering required data. While stakeholders acknowledged that ESC had improved over time, experience took precedence over modelling, both in the decision-making process and when assessing potential woodland sites.

“Modelling has its place. . . it’s nice, it confirms something. But it doesn’t tell you anything you didn’t necessarily know already.”

Forestry agent

## 4. Discussion

### 4.1. Climatic suitability of new woodland

The majority of grant-funded woodland expansion in Lochaber since 1989 has been climatically suited to site conditions. It is unlikely that current climate will be a major barrier to woodland establishment in Lochaber, and for most sites does not limit establishment or growth. Nevertheless, there is still evidence that unsuitable schemes are being accepted, albeit rarely, with 3–12% of new woodland considered unsuited to climatic conditions. Given the requirement for ESC outputs to justify marginal schemes (FCS, 2012), this suggests that evidence is either inappropriate or has been overruled based on local knowledge.

This analysis has assumed climate to be constant over woodland lifetime. However, climate has already changed in Scotland in the last 60 years (Werritty and Sugden, 2013), and Lochaber is predicted to experience warmer, wetter winters and drier summers over the next 30 years (Murphy et al., 2009). This will potentially decrease suitability for key species such as *P. sitchensis* and *P. sylvestris* (Smout, 2006; Petr et al., 2015). Choosing species that are appropriate for future climates is therefore increasingly important, and is receiving much attention in both research (Berry et al., 2002; Broadmeadow, 2005; Ray et al., 2008; Ogden and Innes, 2009; Hanewinkel et al., 2012; Lindner et al., 2014) and in policy (Read et al., 2009; FC, 2011; FCS, 2015). Since 2011 ESC has also included indicative future climate scenarios at the landscape scale (Bathgate, 2011). However, we find little interview evidence that climate change considerations are yet a major factor in woodland planning and species selection among private consultants.

This study is also limited by a 250 m<sup>2</sup> model resolution that cannot fully reflect the complexity of underlying ecological conditions. Microclimates such as sheltered valleys or riparian zones are therefore inadequately represented (Riitters et al., 1997). However, model resolution is higher than alternative models such as WorldClim (Hijmans et al., 2005) and the same as that available to woodland planners. It is unlikely that higher resolution climate modelling would greatly affect results since analysis is constrained by species composition data, which are either unavailable or only available at the whole-woodland scale. Finally, ESC methodology is based on expert-opinion and may inadequately represent site suitability. Nevertheless, site quality judgements are based on empirical observations and experimental trials, while model inputs such as windiness have been shown to perform well in complex landscapes (Suárez et al., 1999; Ray, 2001; Wilson et al., 2001, 2005).

### 4.2. The influence of ecological suitability on Woodland planning

We find strong evidence that ecological suitability is accounted for in site, species and seed provenance selection within the woodland planning process. Spatial evaluation indicates that the vast majority of woodland has been located in climatically suitable areas. Given that woodland location is non-random, this indicates that climate is being taken into account, either through the experience of foresters, or formally within the planning process. This is supported by interview evidence that ecological considerations

inform both species selection and planning approvals. However, we find that ecological suitability appears to play a minor role in regards to woodland type, which is more greatly influenced by grant scheme structure (Dandy, 2012). This aligns with previous indications that grant rates are the greatest determinant of woodland type in Scotland (MindSpace, 2010; WEAG, 2012; Lawrence and Edwards, 2013). Native woodland has comprised 95% of woodland creation in Lochaber despite high suitability and industry pressure for productive forestry. While we recognise the numerous benefits of native woodland (Thomas et al., 2015), this nevertheless conflicts with the Scottish Government’s ambition that 60% of new woodland should be for softwood production (FCS, 2009; WEAG, 2012).

We find some evidence that woodland suitability has improved as a result of stronger emphasis on ESC under the SRDP (FCS, 2012). This is most likely due to modification or rejection of the most unsuitable applications since overall woodland suitability has remained constant. ESC may also have increased transparency of assessment, particularly for non-forestry stakeholders (Nilsson et al., 2008; Chetcuti et al., 2009). However, improvements could have arisen due to increased length and scrutiny of the consultation process under the SRDP. We also found little evidence in interviews that use of or attitudes towards ESC had changed among forestry agents as a result of new requirements. Nevertheless, some held a view that requirements had formalised ecological criteria within decision-making processes. This may reflect a cultural shift in woodland planning, from modifying sites to modifying species selection (Ray and Broome, 2001; Slee, 2007).

Finally, the increased use of ESC mirrors a rise in decision support and modelling tools in many field-based professions (Clare and Ray, 2001; Bernard and Prisley, 2005; Reynolds et al., 2007). We found similar conflicts to those identified by Stewart et al. (2013) between computer-based decision support tools and forestry experience. ESC offers an empirical approach to assessing suitability and is a valuable training tool (Chetcuti et al., 2009; Stewart et al., 2013). However, it strongly relies on the ability of the forester to ‘read’ the site conditions (Ray and Broome, 2001). As such, some agents believed reliance on modelling to be symptomatic of a decline in forestry expertise and outdoor experience (Robbins, 2003; Leslie et al., 2006). Indeed, some argue that essential forestry skills will be lost if decision-making is reduced to a ‘tick-box’ process (Lawrence and Edwards, 2013). This study finds no evidence for this, at least within the woodland planning process. Professional forestry agents continue to be integral to woodland planning, which remains heavily reliant on local knowledge and expert judgment. Given that 90% of projects in Lochaber are agent-led, consistent with figures for the whole of Scotland (CJC Consulting, 2002), it is surprising that forestry agents and have been largely overlooked in research to date (Hujala et al., 2007; Lawrence et al., 2010; Buijs and Lawrence, 2013).

### 4.3. Additional influences on suitability

#### 4.3.1. Soils

Soil is a major factor in determining site suitability for woodland, incorporated into both ESC methodology and the woodland expansion decision-making process (Wilson et al., 2005; FCS, 2012). Interviews findings indicate that soil plays a key role in determining site suitability, particularly due to high variability within and across sites. An absence of high resolution soil data is also commonly recognised as a constraint on suitability modelling (Quine et al., 2002; Bailey et al., 2006). As such, we argue that local soil sampling is critical, and ESC should not be used to determine edaphic suitability without local inputs.



#### 4.3.2. Management

Management factors, particularly grazing and weed growth are perceived as the greatest threats to new woodland establishment in Scotland (Newton et al., 2001). Deer grazing is a major issue in Scottish woodland management, and is a significant barrier to both regeneration of existing woodland and woodland expansion (Staines, 1995; Gill and Morgan, 2010; Tanentzap et al., 2013). While only one study (CJC Consulting, 2002) has evaluated the role of management in grant scheme success, findings are broadly in line with perceptions, with weed growth and grazing the most common threats to new woodlands. We further emphasise the importance of woodland management by demonstrating that, in the majority of cases, success does not appear to be limited by current climatic suitability.

#### 4.3.3. Implementation

We found some evidence that woodland expansion may be limited by logistics and implementation. Difficulties in obtaining local seed sources and planting moratoriums due to pathogens delay or alter schemes after approval (Newton et al., 2001; Spracklen et al., 2013; Fraser et al., 2015). Such threats may become more widespread as the climate warms (Sturrock et al., 2011). Furthermore, deviation between planning and implementation was commonly cited as a reason for failure of woodland expansion projects. Reasons posited for this included staff cuts, fewer training opportunities and cost saving. Funding gaps between grant schemes also undermine confidence and place additional pressure on planning, training and recruitment. This is evidenced by the hiatus in woodland creation between the closure of the SFGS in 2006 and initiation of the SRDP in 2007 (FC, 2014b). Although the implications of grant scheme irregularity have been well documented (Lawrence and Edwards, 2013; Osmond and Upton, 2012; WEAG, 2012), we argue that these disruptions exert considerably wider-reaching pressures across the supply-chain.

### 5. Conclusions

This paper presents an evaluation of woodland grant schemes in Lochaber using site suitability modelling. We find that the majority of grant-funded woodland expansion since 1989 has been suited to site conditions. Moreover, the proportion of suitable woodland has increased from 88% to 97% under the latest woodland grant scheme. This may be due in part to a formalisation of site selection criteria through ecological modelling and a return to the philosophy of matching species to sites. However, it may also be driven by the increased scrutiny of the consultation process, suggesting a potential trade-off between site suitability and administration cost. Overall, it is unlikely that current climate will limit woodland growth and benefits in Lochaber under existing practice. While climate change may alter the suitability of woodland sites, this does not yet appear to strongly influence private woodland design. Emphasis should also be placed on woodland management, particularly in relation to grazing exclusion, in securing woodland grant scheme success.

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### Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.landusepol.2016.03.030>.

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